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THE EFFECT OF CURVATURE OF THE COVER-GLASS UPON MICROMETRY.

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Inasmuch as by far the greater number of observations with the microscope are made upon objects under a cover-glass, it becomes an important subject of inquiry whether microscopic measurements are sensibly affected by the curvature of the covers. Especially is this true as to such experts as profess to be able to identify blood by the measurement of the red corpuscles. I have not been able to find in the literature any investigation of this subject, and having in the Cronin case been called as an expert with reference to the identification of blood by micrometric measurement of the red corpuscles, I made the observations herein recorded not with a view to publication but in order to be able to come to a correct conclusion as to one factor in that case.

In the comparison of long standards this question has no importance whatever, inasmuch as they are always uncovered; but inasmuch as most objectives in common use are corrected for covered objects or are usually so used, the value of one division of the micrometer used with such objectives on covered objects must be determined from a micrometer having its lines covered either permanently or temporarily.

It is obvious that sensible curvature of a cover-glass interposed between the object and front of the objective must affect the amplification of the objective. If such curvature is spherical this effect will be symmetrical. If the curvature is irregular it must distort the object, so that the interval between two objects will appear to be different according to the orientation of the cover-glass.

Several methods are available for testing the curvature. It may be tested by viewing with a telescope the image of some regular object, such as a building reflected from the cover-glass. It may also be tested by accurately focusing a telescope upon some object, such as an artificial star, and then interposing the cover-glass to be tested between the object viewed and the objective of the telescope. If the cover is flat and if its sides are parallel, such interposition will have no effect upon the image other than very slightly to diminish the amount of light received from it. If the cover-glass is spherical it will change the focus of the telescope, which must be refocused in order to obtain a clear image of the object observed. If the cover-glass has irregular curves the image will also be distorted. If the cover-glass is prismatic the image will be displaced laterally.

A very much more sensitive method than either of the above is that by the observation of the Newton's rings caused by placing the cover-glass upon a flat surface. For this purpose I obtained one of Mr. Brashear's justly celebrated flat test sufaces; but having found upon trial that the second method above described was sufficiently sensitive for my purpose, it was used exclusively in the observations hereinafter described. Tested by this method, I may state that nearly all the cover-glasses in common use possess either regular or irregular curvature. Tested by the method of Newton's rings, I am informed by Mr. Brashear that it is practically impossible to find one perfectly flat. I have myself examined and tested a large number furnished me by the courtesy of the Bausch & Lomb Optical Company and The Palmer Slide Company, as well as some purchased of Mr. Zeiss of Jena, and have found a very few that by the second method above described were sensibly flat. By far the greater number possessed quite sensible curvature. My method of determining whether the curvature of the cover-glass sensibly affected micrometric measurements was carefully to measure the same space under identical conditions, except as to the cover-glass, and to compare the results. For this purpose a high-angled dry objective was employed as being more likely to be affected by a variation in the cover-glass than a homogeneous immersion or low-angled objective. The cover-correction was made as perfect as possible and not changed thereafter.

The measurements were all made with a Bausch & Lomb first-class $1/6$ objective (cover-correction $= 0 + 3 + \frac{1}{2} + \frac{2}{10}$), a Bullock filar micrometer, a Smith's vertical illuminator, manufactured by Mr. W. H. Bullock, and a Bullock stand, "Professional No. 2."

The space measured was the second 1–100 mm. of "Centimeter A," counting from the first line of the 1–100 mm. band. The temporary covers, except as otherwise noted, were 16–100 mm. in thickness, and all except Nos. 1, 7, and 9 were taken at random from covers purchased in the ordinary course of trade or furnished by the courtesy of the Bausch & Lomb Optical Company and the Palmer Slide Company. No. 1 was so nearly flat that its curvature, if any, could not be detected by the second telescopic test above described. Nos. 7 and 9 were covers ground and polished to order by Messrs. Bausch & Lomb with the express purpose of making them as nearly flat as possible, but with the effect of making them more curved than covers usually are which have not been thus treated, experience showing that the covers are so easily warped that they cannot by ordinary methods be ground flat.

The measurements are recorded in terms of divisions of the micrometer, of which 1 division = 0.0732 μ. The number at the head of each series refers to the temporary cover used in that series.

Oct. 6, 1889.

No. 1 (flat cover).	No. 2.
131.4 div.	132.4 div.
131.2 “	132.5 “
133.0 “	131.6 “
132.0 “	130.5 “
133.0 “	131.9 “
Mean: 132.1 “	Mean: 131.8 “
No. 3.	**No. 4.**
130.0 div.	131.7 div.
3.3 “	3.9 “
1.9 “	1.0 “
0.7 “	2.9 “
1.8 “	1.0 “
Mean: 131.5 “	Mean: 132.1 “
No. 5.	**No. 6.**
131.9 div.	131.7 div.
1.0 “	1.7 “
1.8 “	2.5 “
1.2 “	2.4 “
1.7 “	1.1 “
Mean: 131.5 “	Mean: 131.9 “

No. 7 (B. & L., ground and polished).

131.9 div.
2.8 “
4.0 “
2.9 “
1.0 “

Mean: 132.5 “

No. 8 (Zeiss).

131.4 div.
1.6 “
0.6 “
1.1 “
1.1 “

Mean: 131.2 “

No. 9 (B. & L., ground and polished).

132.2 div.
3.4 “
2.2 “
2.4 “
1.2 “

Mean: 132.3 “

No. 10 (No. 1 measured again).
(No. 1.)

132.6 div.
3.0 “
1.5 “
4.0 “
2.5 “

Mean: 132.7 “

No. 11 (cover $\frac{8}{100}$ mm. in thickness, and hence, there being no change of the cover correction, bad definition).

132.2 div.
1.8 “
3.1 “
2.5 “
3.7 “

Mean: 132.7 “

No. 12 (No. 1 again).
(No. 1.)

133.0 div.
132.3 “
131.0 “
131.0 “
129.5 “
132.5 “

Mean: 131.6 “

	Mean.	Difference from mean.
(1) (flat cover)	132.1 div.	— 0.1 div.
(2)	131.8 “	+ 0.2 “
(3)	131.5 “	+ 0.5 “
(4)	132.1 “	— 0.1 “
(5)	131.5 “	+ 0.5 “
(6)	131.9 “	+ 0.1 “
(7) (B. & L.)	132.5 “	— 0.5 “
(8) (Zeiss)	131.2 “	+ 0.8 “
(9) (B. & L.)	132.3 “	— 0.3 “
(10) (1, second time)	132.7 “	— 0.7 “
(11) (cover $\frac{8}{100}$ mm.)	132.7 “	— 0.7 “
(12) (1, third time)	131.6 “	+ 0.4 “
Mean of all 12 series	132.0 “	

Mean of all, excepting the series with the thin cover (No. 11), = 131.9 div.

Mean of the eight series, excluding the three series of measurements with No. 1 and the series with the thin cover, = 131.9 div.

Mean of the three series of measurements with No. 1, the flat cover, = 132.1.

An inspection of the above measurements discloses the fact that the differences from the mean in the case of the three series in which the flat cover was used are as great as when other covers were used, and that the mean of all the measurements using the flat cover is sensibly the same as with the other covers (some of which possessed a curvature quite sensible), the difference being only 0.02 μ., which is too small to measure.

It was intended to make a much larger series of measurements, but the pressure of other work prevented.

The foregoing are, however, sufficient to warrant the conclusion (to which there may possibly, in the case of very bad covers, be some exceptions) that using good cover-glass, such as is furnished by reputable dealers in this country, the most, if not all, of which is manufactured by Chance, the influence of the curvature of such covers is practically *nil.*

This is not the conclusion to which the writer had come from *a priori* reasoning ; but it is the only one warranted by such facts as have been observed. Further observations will be presented in a future paper.